IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 6 Issue 5, May 2019
ISSN (Online) 2348 – 7968
www.ijiset.com

Study of the unburned carbon content of ash and propose one new technology separated the ash and unburned carbon discharged by the coal-fire thermal power plants in Vietnam

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Abstract

At present, the domestic coal supply for coal-fired thermal power plants is gradually decreasing, while the number of coal-fired thermal power plants is increasing. So, we have to import coal to compensate for the shortage of coal supply.
The amount of ash discharged by the coal-fire thermal power plants is very huge. According to statistics data, by 2015, vietnamese coal-fired power plants discharged nearly 8.5 million tons of ash. In Viet Nam, the combustion process of coal in boilers of coal-fired power plants has almost been optimized, but the ash still contains substantially unburnt carbon. So if we separate refuse (waste) into coal and ash, we will get an important source of coal and ash for many industries.
This article estimates the potential and the reserves of ash as well as the technologies currently used in Vietnam and in the world.
Finally, by studying the theory of unburned carbon content in ash, it is proposed some technologies for separate the unburning carbon and ash that is highly applicable to coal-fired thermal power plants in Vietnam.

Key words: *Coal-fired thermal power plant, Ash, Coal*

1. Introduction

Figure 1 shows the diagram of installed capacity of coal-fired thermal power plants in Vietnam as well as coal consumption and ash generated in the period from 2007-2015 [1].

In the figure 1, we see that in the early years of industrial development in Viet Nam, power output increased significantly, especially from 2011 to 2015. The total installed capacity of coal-fired thermal power plants has increased rapidly corresponds to three times of coal consumed and the amount of ash emitted is 3 times higher. The amount of ash discharged by coal-fired thermal power plants by 2015 is about 8,415 thousand tons while the reuse amount only is about 20% corresponds. This is only small-scale use. So, the environment will automatically be polluted.

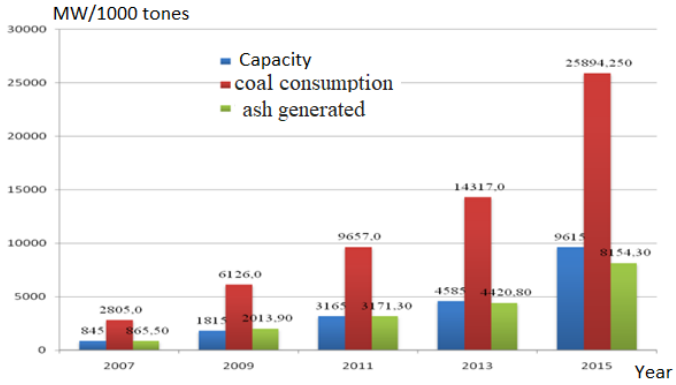

Fig. 1 The Statistics of installed capacity, coal consumption, ash created of coal-fired thermal power plants in the 2007-2015 period

According to data from the industrial safety techniques and environment agency (Vietnamese Ministry of Industry and Trade), by 2017, the amount of ash generated from 23 operating coal-fired thermal power plants (or simply call thermal power plant) in Viet Nam is up to 12.2 million tons, According to the 7th adjusted Electricity Plan by 2030, there will be 46 coal-fired thermal power plants in operation with a total nominal capacity of 41,500 MW. Therefore, in the next few years, if there is no solution to solve this problem, the risk of ash over the permitted limit is an obvious fact.

2. Analysis the ash discharged by the coal - fire thermal power plants in Viet Nam

2.1. Notion of ash

There are mostly two main categories of ash discharged by the coal-fire thermal power plants in Vietnam:
- *Bottom Ash is collected mainly in the bottom of the boiler*

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- Fly Ash is collected from a dust filter funnel such as an electrostatic precipitor system – ESP

Fig. 2 Image of fly ash

The biggest difference between bottom ash and fly ash is the size of the particles. Bottom ash particle is larger size than fly ash one. Depending on the combustion technology (type of boiler) and the combustion regime as well as the quality of coal, different types of coal with which the mass percentages of bottom ash and fly ash are also different. For example, with the same condition and the same coal supply, for the Circulating fluidized bed boiler, there are 40-50% bottom ash and 50 to 60% fly ash, while for coal fired boiler (or Pulverized coal-fired boiler), there are 10-20% bottom ash and 80-90% fly ash.

2.2. The composition of the Vietnamese ash

As we know, the chemical properties of fly ash are influenced to a great extent by the properties of the coal being burned and the combustion techniques used. There are four principle types of coal (anthracite, bituminous, sub-bituminous and lignite), each vary in higher calorific value (HCV), chemical composition, ash content, and geological origin.

So far, most coal-fired thermal power plants in Vietnam have used domestic anthracite coal, [2], [3], [4], [5], [6], [7], [8], [9], [10], which is characterized by high calorific value, low volatile content.

There is still a large amount of carbon lost during combustion as shown in Table 1 from some different vietnamese coal-fired power plants tested such as Pha Lai 1 and 2, Uong Bi, Ninh Binh.

Table 1. Chemical composition of the Vietnamese fly ashes and clay

	Thermal power Plant			***Clay***		
Chemical composition	***Phả Lại 1,2***	***Uông Bí***	***Ninh Bình***	***Type A***	***Type B***	***Type C***
SiO_2	58.4	58.5	60.7	59.6	65	63
Al_2O_3	26.1	28.1	27.2	15.8	15.5	16
Fe_2O_3	7.2	6.1	4.8	9.3	7.2	9.0
CaO	0.7	0.8	0.4	1.7	0.6	0
MgO	1.2	1.1	0.8	3.2	0.7	0.5
Na_2O	0.4	0.1	0.2	0.2	0.1	0.2
K_2O	4.3	2.6	4.3	2.3	3.0	2.8
SO_3	0.3	-	0.3	0	0	0
(LOI) %	15-35	20-45	20-40	8.1	6.5	6.1

The analytical results in Table 1 [6] show that the chemical composition of ash is almost equivalent to clay, especially the three main components: Silicate (SiO_2), Oxide Aluminum (Al_2O_3) and Oxide Iron (Fe_2O_3). From these chemical compositions, it can be confirmed that most of the coal ash in Vietnam is of type F according to ASTM, which means that this ash is almost non-reactive directly to water. This is different with other the type of ash used in neighboring countries like Thailand and China.

According to the Prospectus of the Factory premixed dry mortar production Da Cao Cuong, on average, Pha Lai 2 Thermal Power Plant (Hai Duong) daily discharges 3,000 tons ash, of which 30% is unburnt coal, the rest is bottom ash and fly ash [6], [13], [15]. The amount of coal left in ash is very large. However, this amount of coal is not reused as fuel for boiler etc. and moreover this high carbon content affects the quality of products produced from ash. That is reason why we need to separate the amount of unburnt carbon in ash.

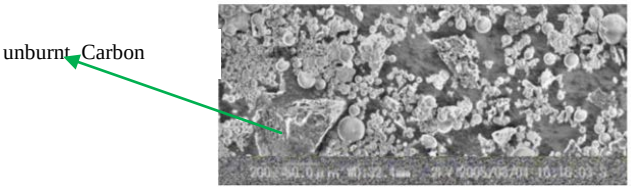


Fig. 3 the original ash

The figures 3,4,5 give us the images of original ash, the ash after separation, the unburnt carbon after separation of the Pha Lai thermal power plant by the Scanning Electron Microscope (SEM) which preforms the best. Its analytical performance was used to study the morphology of the ash particles.

It can be seen in figure 3 that there're many kinds of particles such as the round particles with different dimensions and the angular particles of unburnt carbon.

The figure 4 give us the image of ash after separation, most of the particles in figure 4 have an absolutely round shape, and very few angular particles (unburnt carbon).

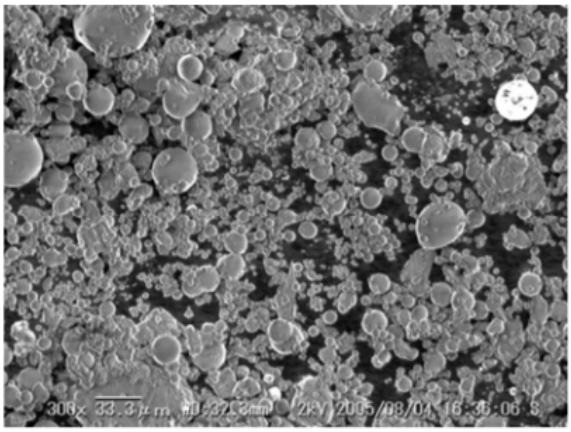


Fig.4 The ash after separation

The typical SEM photomicrographs of the ash after separation is shown in Figure 4. Usually, fly ash composed of mostly small and spherical particles. Figure 4 consists of almost regular spherical (cenospheres) particles ranging about 1 µm to 9 µm in diameter and some particles have their diameter more than 10 µm.

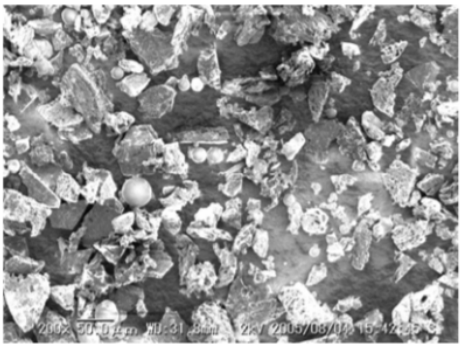


Fig. 5 the unburnt carbon after separation

The fact shows that the application of ash (the quality of the ash) depends on the unburnt carbon content which is normally limited to a maximum content of 12% (ASTM C618). Fly ash with a high unburnt carbon content will not guarantee the mechanical properties of concrete. That's mean to reuse ash as construction material, the unburnt carbon content must be less than the specified value of ash for each corresponding construction material. If unburnt carbon will affect the uniformity of the material.

2.3. Applications of ash in Viet Nam

The Factory premixed dry mortar production Da Cao Cuong produce products: red brick mortar plastering, plastering mortar concrete brick, plastered brick mortar lightweight AAC (Aerated Autoclaved Concrete), leveling mortar, glue the titles etc. The main applications of ash are as follows:

2.3.1. Using ash as an additive in the production of Portland cement [3], [4], [5].

It is possible to use the fly ash in the cement industry. There are essentially two main applications for fly ash in cement production, first as a raw material to produce Portland clinker and second as a pozzolanic addition.

2.3.2. Possibility Applicability of ash for non-fired brick production technology

AAC brick (figure 6) [12]. [13]. is produced from the main source of fly ash, lime, cement, gypsum and aluminum powder and raw materials, auxiliary fuels for production.

Fig. 6 The production of Aerated Autoclaved Concrete brick at the Song Da Cao Cuong Froth flotation factory in Viet Nam

2.3.3. Road sub-base

Ash after separation cements have been used in embankment soil stabilization, sub-grade base materials, as aggregate filler. In fact, the shear strength is an important characteristic for soil stabilization using separated fly, which is partially due to separated fly pozzolanicity.

3. Technology of treatment unburnt carbon in the ash

Thermal power plants discharge extremely large amounts of ash as industrial waste. For example, the medium capacity thermal power plant such as Pha Lai 2 discharge daily 3000 tons of ash, of which 30% is unburnt coal, the rest is fly ash. Since this residual carbon content is not high, it is difficult to utilize as fuel, so it's discharged directly into the landfills. But the potential for using fly ash in Vietnam is very large. However, at present, the utilization

rate is still very limited, there are only a few factories such as Pha Lai, Hai Phong thermal power plants wich have high rates of used ash. The main reason is that the ash of these plants has not met the required quality as raw materials for cement, concrete or other applications. So, we have to reduce the amount of carbon in the ash to fulfill all the technical requirements of these ash applications.

There are currently many technologies in the world to separate unburnt carbon content in ash to ensure fly ash quality requirements for use in cement, concrete and other applications,[14], [15], [16], [17]. These technologies are:

3.1. The centrifugal classifier method

The method of centrifugal classifier (figure 7) has a suitable recirculating air flow wich allows the separation requirements to be fine-tuned and hence high quality of separation with different dimensions of particles is achieved.

Normally unburnt carbons are large fly ash particles, this separation method is useful for reducing carbon content in fly ash. The effectiveness of this method depends on mass, size and shape of particles distributed separately. In the case of unburnt carbon available in fine ash particles, this technology will not be effective to reduce carbon. In this case, the carbon still exists in ash due to the smaller density of coal of fly ash particles of the same size.

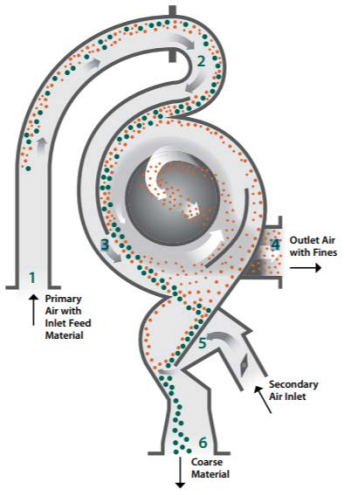
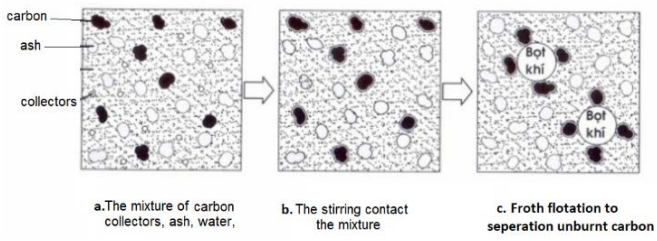


Fig.7 Diagram describing the centrifugal classifier technology

3.2. Froth flotation method

Froth flotation technology (figure 8) has been successfully applied in Song da Cao Cuong froth flotation factory [6] in Viet Nam that use the ash from the thermal power plants.



(a)

(b)

Fig. 8 Diagram describing the technology
(a) The froth flotation process
(b) Song Da Cao Cuong Froth flotation factory in Viet Nam

In Froth flotation process, particles of interest are physically separated from a liquid phase as a result of differences in the ability of air bubbles in the solution produced by the stirrer under the effect of the collectors have attracted unburnt coal particles and bring them to the surface where the clean coal is recovered and dried. The rest of the bottom ash can be used as a cement and material additive. The diameter less than 5μm of carbon is one of the advantages of froth flotation technology. The biggest disadvantage of this technology requires a relatively large area and needs to provide a large amount of water during the process.

3.3. Triboelectricstatic separation Method

In fact, the use of froth flotation method is only applicable in inland. However, many thermal power plants of Vietnam are near the sea where the water is very rare and saline so the flotation method is no longer suitable. So, we try to find out a new method of high applicability and feasibility in Vietnam

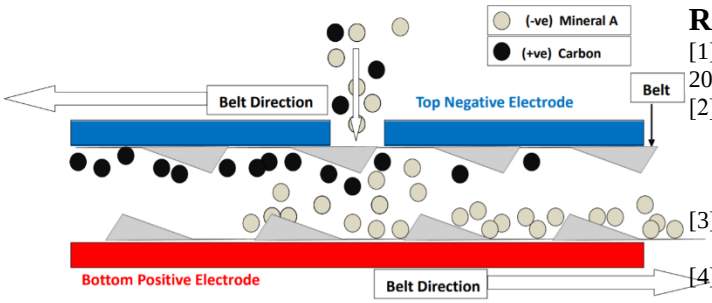


Fig. 9 Carbon particles charge positive in fresh ash processing of the Triboelectricstatic separation Method

The Triboelectricstatic separation process is described in the figure 9. The electronegative of carbon is 2.55, so the charge of carbon particles of ash in the thermal power plant are positives and the one of mineral particles are negative. and the negatively charged mineral are attracted to opposite electrodes. The particles are then swept up by a continuous moving open-mesh belt and conveyed in opposite directions. The belt moves the particles adjacent to each electrode toward opposite ends of the separator [10].

4. Conclusion

In this article, the analysis and evaluation of some ash separation technologies is presented. The new method is triboelectrification phenomena that studied and have been briefly reviewed.

- Currently the treatment of bottom ash and fly used in many countries around the world wich contributes to increase the amount of coal significantly to supply the coal market (millions of tons). For example, suppose if the amount of carbon obtained is about 20% of the ash generated from coal-fired power plants in Vietnam, the amount of clean coal obtained by applying these technologies is also about 2, 5 million tons.
- The treatment of ash will also reduce the environmental pollution in the areas around the thermal power plant.
- The treatment of ash will also save the land area used for ash storage, especially in tourist areas such as Quang Ninh or main agricultural provinces such as the Mekong Delta and Thai Binh, Nam Dinh etc. in Viet Nam
- After analyzing theoretically, the advantages and disadvantages of the methods, the method is most appropriate for the coal-fired thermal power plants in Vietnam is triboelectrostatic separation technology.

In the next article will refers to the calculation of the factory separating coal from ash using triboelectricstatic method.

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